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Specification

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## Light Guide and Image Reader

### Technical Field

[001] The present invention relates to a light guide for illuminating documents in a line shape in facsimile machines, copying machines, scanners and the like, and an image reader having this light guide incorporated therein.

### Background Art

[002] There is proposed, for the purpose of effectively irradiating the object of irradiation with lights from light sources, what uses a light guide whose section is a paraboloid (see Patent Document 1 for instance).

[003] There is also known a compound parabolic concentrator (CPC) which is intended to enhance the efficiency of concentration with no regard for image formation performance (Non-Patent Document 1).

Patent Document 1: Japanese Patent Laid-Open No. 2001-330734

Non-Patent Document 1: Title of book – No. 6, Pencil of Light 5: Non-Image Forming Light Concentrating Optical System; Author – Tadao Tsuruta

### Disclosure of the Invention

#### Problems to be Solved by the Invention

[004] Lights emitted from a light guide expand. As a result, where the distance between the document and the emitting face is great, the illumination of the face of the document may decline, which is not desirable.

[005] Incidentally, as stated in Non-Patent Document 1, a compound parabolic concentrator (CPC) is an optical system devised for efficient concentration of lights, and has a

characteristic that all the lights incident on the light receiving face at an angle of incidence not greater than  $\theta$  concentrate on the light concentration face.

[006] Then, an object of the present invention is to provide a light guide capable of minimizing the expansion of light by conversely utilizing the characteristic of the compound parabolic concentrator (CPC) to convert scattered lights extending over a full angle from a limited area into radiant lights confined to a prescribed emission angle and using them as an optical system efficiently illuminating the face of the document, and a line illuminator using that light guide.

#### Means for Solving the Problems

[007] The light guide pertaining to the invention for solving the problem noted above emits lights incident from an end face from an emitting face disposed along the longitudinal direction while having the lights reflected by the internal face thereof, wherein the sectional shape thereof in a direction orthogonal to the longitudinal direction of this light guide has two opposite parabolas, a line segment connecting the focal points of the two opposite parabolas and a line segment corresponding to the emitting face. The face containing the line segment connecting the focal points of the two opposite parabolas constitutes the reflective face and the face opposite to this reflective face constitutes the emitting face.

[008] The configuration described above makes it possible to restrain the expansion of lights emitted from the emitting face. In order to emit lights most efficiently, it is preferable to arrange the side faces of the light guide on the emitting face side substantially in parallel with the optical axis.

[009] An image reader pertaining to the invention has two pairs, for instance, of illuminating units each provided with a light source on one end or both ends of the light guide, and the

illuminating units are so arranged as to cause lights emitted from the emitting faces to irradiate the same area of the face to be read of the document.

#### Advantages of the Invention

[0010] The light guide according to the invention and the line illuminator using that light guide, since they conversely utilize the characteristic of the compound parabolic concentrator (CPC) to convert diffused lights extending over a full angle from a limited area into radiant lights confined to a prescribed emission angle and use them as an optical system efficiently illuminating the face of the document, can minimize the expansion of lights. This makes it possible to efficiently illuminate the face of the document.

#### Brief Description of the Drawings

[0011] Figure 1 is a diagram showing the sectional shape of the light guide according to the present invention having a compound parabolic shape;

[0012] Figure 2 is a diagram showing the emitted lights of the light guide according to the invention shown in Figure 1;

[0013] Figure 3 is a sectional view of a contact image sensor (CIS) provided with a line illuminator in which the light guide according to the invention is incorporated;

[0014] Figure 4 is a diagram showing the fitting positions of light emitting diodes as light sources disposed on an end face of the light guide according to the invention;

[0015] Figure 5 is a diagram showing the sectional shape of another light guide according to the invention;

[0016] Figure 6 is a diagram showing the sectional shape of another light guide according to the invention; and

[0017] Figure 7 is a diagram showing the sectional shape of a line illuminator provided with a compound parabolic reflector.

#### Best Modes for Carrying Out the Invention

[0018] The best modes for carrying out the present invention will be described below with reference to the accompanying drawings. Figure 1 shows the sectional shape of a light guide according to the invention having a compound parabolic shape. Figure 2 is a diagram showing the emitted lights of the light guide according to the invention shown in Figure 1.

[0019] A light guide 10 is formed of a transparent resin, such as acryl for instance, and its sectional shape is constant over the full length (e.g. 320 mm) of the light guide 10.

[0020] The bottom face 1 of the light guide 10 measures 0.52 mm in width W, and a scattering pattern consisting of white ink or fine convexes and concaves is formed on this bottom face

1. The scattering pattern is formed in dots for instance.

[0021] This scattering pattern may be formed all over the bottom face 1, but the area in which the scattering pattern is formed may also become greater with an increase in distance from the end face on which lights from light sources, not shown, come incident.

[0022] A side face 2 is part of a curve resulting from the rotation of a quadratic curve ( $y = 0.81927x^2 - 0.30515$ ) represented by a virtual line around the origin  $(x, y) = (0, 0)$  as the center of rotation by  $\theta = 10$  degrees and displaced in parallel by  $-W1/2 = -0.26$  mm in the direction of the x axis (the range of y:  $0 \leq y \leq 9.97$ ). By inclining the quadratic curve represented by the virtual line, the side face 2 on the emitting face 4 side is made substantially parallel to the y axis (the optical axis). A side face 3 is a curve symmetric to the side face 2 with respect to the y axis.

[0023] In this case, the coordinate  $(x, y) = (-0.26, 0)$  is the focal point a of the side face 2, which is a paraboloid. As shown in Figure 2, out of the scattered lights from this focal point a, lights having directly reached the side face 2 satisfy every condition of reflection, and reach the emitting face 4 as parallel lights inclined at 10 degrees to the y axis within the light guide 10.

[0024] Where the light guide 10 is made of acryl whose refractive index  $n = 1.49$ :

$$1.49 \cdot \sin 10^\circ = \sin \theta d \text{ (Snell's law)}$$

[0025] Hence  $\theta d = 15^\circ$ .

[0026] Therefore, like the light ray represented by reference numeral 5 in Figure 2, parallel lights inclined at 15 degrees to the y axis are emitted from the emitting face 4.

[0027] On the other hand, out of the scattered lights from the focal point a, lights having directly reached the emitting face 4 are inclined by -15 degrees to the y axis when they pass the coordinate  $(x, y) = (1.50, 9.97)$  like the light ray represented by reference numeral 6 in Figure 2.

[0028] Similarly, the coordinate  $(x, y) = (0.26, 0)$  is the focal point b of the side face 3, which is a paraboloid. Out of the scattered lights from this focal point b, lights having directly reached the side face 3 satisfy every condition of reflection, and reach the emitting face 4 as parallel lights inclined at -10 degrees to the y axis within the light guide 10.

[0029] Therefore, scattered lights from the section  $(-0.26 \leq x \leq 0.26, y = 0)$  (namely the scattered lights from the bottom face 1), including the reflection of the scattered lights directly reaching the side face 3, are confined to a range of  $\pm 15$  degrees to the y axis.

[0030] This makes it possible to prevent the expansion of lights emitted from the emitting face 4 from becoming too wide, with the result that the face of the document can be efficiently illuminated.

[0031] Figure 3 is a sectional view of a contact image sensor (CIS) provided with a line illuminator in which the light guide according to the invention is incorporated, and Figure 4, a diagram showing the fitting positions of light emitting diodes as light sources disposed on an end face of the light guide according to the invention.

[0032] A contact image sensor (CIS) 30 shown in Figure 3 is provided with a box 31; two pairs of line illuminators 20L and 20R are built into this box 31; a lens array 32 of an erecting unit magnification system is arranged in the box 31; and further a substrate 34 provided with a line image sensor 33 is fitted into the lower part of the box 31. Reference numeral 35 denotes a cover glass constituting a document mount.

[0033] Each of the line illuminators 20L and 20R comprises the light guide 10 shown in Figure 1 and Figure 2, a light guide case 11, and a light source board (not shown) provided with light emitting diodes 12R, 12G and 12B shown in Figure 4. The light emitting diodes 12R, 12G and 12B respectively emit red, green and blue lights, and these light emitting diodes 12R, 12G and 12B are chip type diodes (LED chips).

[0034] In this mode for implementing the invention, as shown in Figure 4, the light emitting diodes 12R, 12G and 12B are arranged in a row along the y axis (the optical axis). This makes the normal of the scattered dot pattern formed on the bottom face 1 of the light guide 10 coincide with the optical axis of the light emitting diodes 12R, 12G and 12B.

[0035] Lights from the light emitting diodes 12R, 12G and 12B propagate within the light guide 10, and cause scattered lights to be generated on the bottom face 1. As shown in Figure 3,

these scattered lights are reflected by the side faces 2 and 3, or directly emitted from the emitting face 4 and constitute illuminating lights 7 to illuminate the face to be read of the document, not shown, mounted on a cover glass 35.

[0036] The illuminating lights 7 reflected by the face to be read of the document, not shown, are detected by the line image sensor 33 via the cover glass 35 and the lens array 32. This causes the document to be read.

[0037] Since the illuminating lights emitted from the light guide 10 are confined to the range of  $\pm 15$  degrees to the y axis (the optical axis), the expansion of the illuminating lights is prevented from becoming too wide even where the distance to the document is long. Therefore, the face of the document can be efficiently illuminated.

[0038] Figure 5 is a diagram showing the sectional shape of another light guide according to the invention. A light guide 10A shown in Figure 5 has an emitting face 8 made convex to reduce the expanding angle of emitted lights.

[0039] Figure 6 is a diagram showing the sectional shape of another light guide according to the invention. The sectional shape in a direction orthogonal to the longitudinal direction of this light guide has side faces 2' and 3' each of an oval curve, a bottom face 1' and an emitting face 4', and the two ends of the bottom face 1' coincide with the respective focal points a' and b' of the side faces 2' and 3'.

[0040] Thus, to figure out the coordinate of a focal point from an oval curve  $(x/1.6)^2 + (y/6)^2 = 1$  having an aspect ratio of 1.6:6:

$$x = 0, y = f = -(6 \times 6 - 1.6 \times 1.6)^{0.5}$$

is given. Wherein y is a variation in the section:

$$(f \leq y \leq 0), f = -(6 \times 6 - 1.6 \times 1.6)^{0.5}$$

and the oval curve in that section is:

$$x = 1.6(1 - (y/6)^2)^{0.5}$$

Now,

$$x \text{ where } y = f \text{ being supposed to be } x_0 (= 0.42667)$$

by making the side faces of the light guide curves of which

$$x = 1.6(1 - (y/6)^2)^{0.5} - x_0/2,$$

the two ends of the bottom face 1' are made coincident with the focal points a' and b' of the side faces (oval curves) 2' and 3'.

[0041] When light guides of the type shown in Figure 6 were used as 20L and 20R shown in Figure 3, substantially equal outputs to those where light guides of the type shown in Figure 1 were used were detected by the sensor 33.

[0042] Besides the illustrated examples described above, the paraboloids 2 and 3 or the oval curves 2' and 3' may be made asymmetric between right and left to differentiate the right and left angles of expansion.

[0043] Figure 7 is a diagram showing the sectional shape of a line illuminator provided with a compound parabolic reflector. A line illuminator 60 shown in Figure 7 is such that lights emitted from the emitting face 62 of a light guide 61, whose sectional shape is rectangular for instance, are caused to be reflected by reflectors 63 and 64 having paraboloidal side faces to be emitted as illuminating lights from an opening 65. Reference numeral 66 denotes a plastic case. This line illuminator 60, as it has no reflective face in the refractive index medium, serves to restrain the angle of expansion. Thus, since the contents of the compound parabolic reflectors 63 and 64 are air, lights do not expand when they are emitted from the opening 65, which is the outlet of illuminating lights.